Effects of Fish Density on Water Quality in the New Haul-out Bucket and Fish-haul Trucks at the Tracy Fish Collection Facility

Investigators

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Summary

The U.S. Bureau of Reclamation (Reclamation), Tracy Fish Collection Facility (TFCF) is located at the head of the Delta-Mendota Canal (DMC) 4 km northeast of the C.W. "Bill" Jones Pumping Plant (JPP) and 14.5 km northwest of Tracy, California, and was developed as a means of salvaging Chinook salmon (*Oncorhynchus tshawytscha*) and striped bass (*Morone saxatilis*) ≥20 mm prior to encountering the JPP. After salvage, fish are maintained in holding tanks (6.1 m wide × 5.0 m deep) until transported back to the SSJD as deemed necessary by the current Biological Opinion (BO) and at densities recommended by the Bates fish hauling tables. Subsequent to transport, fish accumulated in a holding tank are collected in a haul-out bucket (1544.3 L, 1.75 m inside diameter with a conical bottom that goes from 0.86 m deep to 1.3 m deep) and transferred to a fish-haul truck tank (9,462.5 L, 4.6 m long ×2.0 m wide × 1.2 m deep). Fish are then trucked 49.9 km from Reclamation's TFCF to one of two release sites outside of the immediate influence of south SSJD pumping facilities.

Maintenance of adequate water quality levels *e.g.*, temperature, dissolved oxygen (DO), CO_2, pH, total ammonia nitrogen (TAN) and total gas saturation (TGS), is of particular concern during fish loading and transport. Water quality in the bucket and trucks can affect the success of fish transportation, as adverse conditions impair important physiological processes, ultimately affecting health and reducing fish performance and survival (Moyle and Cech 2004, Portz *et al.* 2006). Elevated fish densities in the bucket and truck can increase the rate of O_2 consumption and cause hypoxic or anoxic conditions. Low O_2 levels can result in respiratory stress, which can affect swimming performance, equilibrium, and survival (Moyle and Cech 2004, Herbert and Steffensen 2005, Portz *et al*. 2006). As a byproduct of metabolic processes, fish produce CO_2 (approximately 1.4 mg CO_2 per 1.0 mg O_2 consumed under aerobic conditions), which can threaten health in transport containers as elevated levels are toxic to fish and can result in hypercapnia and respiratory distress (Colt and Tchobanoglous 1981, Wedemeyer 1996, Cech and Crocker 2002). Elevated CO_2 also functions in

lowering water pH and creating acidic conditions, which effects ion transport at the gills and leads to blood acidosis (Wood and McDonald 1982, Wedemeyer 1996). Elevated ammonia levels are also of concern during fish transport, particularly the un-ionized ammonia (NH_3^+), which increases with increasing temperature, salinity, and pH, is extremely toxic to fish, and can result in loss of equilibrium and eventually fish mortality (Russo and Thurston 1991).

In 2008, Sutphin and Wu reported fish density (0.3–64.5 g of fish/L) and water quality parameters of concern in the bucket and trucks generally remained within acceptable ranges throughout the period of fish transport at temperatures between 15.2–25.3°C. Since then, a new haul-out bucket and new fish-haul trucks have been designed, fabricated, and are being used at the TFCF. This new equipment must be evaluated, in a similar manner as the old bucket and trucks (see Sutphin and Wu 2008), in order to determine the effects of fish density on important water quality parameters at the onset, throughout, and at the end of transport. Determining the efficiency of the new system in maintaining temperature and O_2 production is also important for the development of updated fish transport tables.

Problem Statement

A new haul-out bucket and new fish-haul trucks have been designed, fabricated, and are being used at the TFCF. This new equipment must be evaluated to determine the effects of fish density on important water quality parameters at the onset, throughout, and at the end transport. Evaluation of this new equipment, paired with the development of updated fish transport tables, will increase the likelihood that the millions of fish that are salvaged annually, including the threatened delta smelt (*Hypomesus transpacificus*) and endangered winter-run Chinook salmon (Reclamation's Tracy Fish Salvage Records 2009), are transported to release sites under appropriate water quality parameters.

Goals and Hypotheses

Goals:

1. Measure volume of the new haul-out bucket and fish-haul trucks and measure water loss due to sloshing during haul-out activity.

2. Develop a linear regression relationship of the amount of salt added vs. salinity in the new truck and monitor salt dissolving rate.

3. Determine rate of temperature rise, in 1 h, with no gas flow, with air flow only, with O_2 flow only and with air and O_2 flow in the new truck.

4. Measure the rate of O_2 rise while operating the air system only, O_2 system only and both air and O_2 systems in the new truck.

5. Measure changes in temperature, DO, CO_2, pH, TAN, and TGS during loading in the bucket and during transport in the new trucks and determine group O_2 consumption and ammonia production.

6. Measure how changes in water quality are affected by estimated fish densities in the new bucket and trucks.
7. Measure the time it takes to complete all components of the haul-out process, as well as the total time, while using the new equipment.

Hypotheses:

1. The salinity gradient in the truck will increase as the target truck salinity increases. The salt dissolving rate will be greater when using the venturi than when dumping salt directly into the truck. The dissolving rate, for both methods of insertion, will increase during warm conditions and will decrease during cold conditions.

2. There will be no difference in the rate of temperature rise in the new trucks, in 1 h, with no gas flow, with air flow only (ambient, seasonally warm), with O_2 flow only, and with both air and O_2 flow.

3. The rate of O_2 rise in the new truck will be significantly greater while operating the O_2 system only and will be the significantly lower when operating the air system only. Operating both the air and O_2 system will result in an insignificant rate of O_2 rise due to O_2 dissipation.

4. As densities of fish increase during loading and transport, TAN, CO_2 and TGS will increase while pH and O_2 will decrease.

5. The average time that it takes from fish loading to fish release while using the new equipment will not be different than that found by Sutphin and Wu in 2008 while using the old equipment (79.8 min).

6. Average water loss, due to sloshing, in the new trucks during transport of fish will be negligible and will be less than that found by Sutphin and Wu in 2008 while using the old truck (147 L on average).

Materials and Methods

Volume of New Haul-out Bucket and Fish-haul Trucks

In order to accurately calculate water volume loss and fish density during the haul-out process, it is necessary to estimate the water volume of the new bucket and trucks as a function of depth. Manufacturer details suggest the maximum water capacity of the new bucket is 1,544.3 L while the maximum capacity of the new truck tank is 9,462.5 L. In order to verify these values, the volume of each will be estimated using salinity. The salinity of the ambient Delta water that is used to fill the truck will be determined. After this, a known amount of dry salt (20 kg) will be added to the venturi tank that is used to rapidly dissolve salt into the Delta water that is introduced into the fish-haul truck. The bucket and truck will then be completely filled using only the water going through the venturi. The salinity in the venturi tank will be monitored using a YSI-85 oxygen, conductivity, salinity, and temperature meter (Yellow Springs, Inc., Yellow Springs, Ohio). When the salinity in the venturi tank returns to ambient Delta water levels it will be assumed that all of the salt had been dissolved in the water and delivered to the truck tank or bucket. We will then determine the salinity of the water in the truck using a YSI-85. Measurements of salinity, in both the bucket and the truck, will be taken at the surface, mid-water, and bottom until they are uniform throughout the water column. The salinity, along with the amount of dry salt added, will allow us to accurately calculate the volume of both the new bucket and trucks at the TFCF.

This process will then be completed by partially filling the truck to known water levels, measured by distance (cm) from the top of the tank. This information will be used to determine the volume of water lost, as a function of depth, during the Water Quality and Hauling Truck Fish Density evaluation.

Amount of Salt to Add and Salt Dissolving Rate

A linear regression relationship of the amount of salt added vs. the salinity in the truck will be developed by dumping varying known amounts of salt into the venturi tank and completely filling the truck using only the water going through the venturi. The salinity in the venturi will be monitored in the same manner as previously described. We will then determine the ending salinity in the truck tank using a YSI-85. Measurements of salinity will be taken at the surface, mid-water, and bottom. This information will allow us to develop a linear regression relationship of the amount of salt added vs. the salinity in the truck which will be used to determine the necessary amount of salt to add to the tank in order to achieve a concentration of 8 mg/L, which is the salinity required in the truck by the current BO.

The amount of salt that is determined to achieve a concentration of 8 mg/L will be introduced into the truck in two separate ways: (1) by utilizing the venturi and (2) by dumping salt directly into the truck. This simulates the two ways in which salt is added to the trucks during regular operations at the TFCF. The same amount of salt will be used for each method so that the maximum salinity will be the same. Salinity measurements of the water in the truck will be taken at the surface, mid-water, and bottom using a YSI-85. Water temperatures (surface, mid-water, and bottom) will be taken throughout each trial and will be measured with a YSI-85. The O_2 system will be turned on to promote thorough mixing of water in the truck during these trials.

Introducing salt into the truck using the venturi system should allow us to verify the estimated volume of the truck and the appropriate amount of salt to add in order to achieve a concentration of 8 mg/L. The salinity in the venturi tank will be monitored as previously described. When the truck tank is filled with the venturi system the salt should be completely dissolved by the time it is introduced into the tank and the concentration of salt in the full truck should be approximately 8 mg/L if our estimated volume is correct. The salt dissolving rate, while using the venturi, will be calculated. The salinity reached while using the venturi to fill the truck will be assumed to be the concentration at which all salt has dissolved when performing the salt dissolving rate evaluation at which the salt will be dumped directly into the truck.

Dumping the pre-determined amount directly into the truck will allow us to determine the salt dissolving rate at that particular water temperature. Salinity measurements will be taken immediately after dumping the salt into the truck and every 10 min thereafter until a concentration of 8 ppt, or the maximum concentration achieved in the venturi trials, is reached throughout the tank. This will be done during warm and cold conditions. This information allows us to determine the salt dissolving rate during warm and cold conditions as well as if, or when, an appropriate salt concentration is reached during the period of fish transport when salt is dumped directly into the tank of the truck.

Rate of Temperature Rise

The rate of temperature rise in 8 mg/L salt water with no gas flow, with air flow only (6 L/min per airstone), with O_2 flow only (6 L/min per airstone), and with both air and O_2 flow (6 L/min per airstone) will be determined in the new truck. The different treatments are necessary due to the fact that the compressed air system pumps and heats ambient air (seasonally hot) into the water in the truck, whereas the O_2 system injects cold, compressed oxygen into the water contained in the truck. These trials will be completed during the warmest season and time of day in order to test the rate of temperature rise, for each treatment, during the worst case scenario. Ambient air and Delta water temperatures will be measured before and after every replicate using an Acu-Rite digital thermometer (Acu-Rite Companies Inc., Paramount, California) and a YSI-85, respectively. The truck will be filled with water containing salt in a concentration of 8 mg/L and will then be parked in the direct sunlight for a period of 90 min. Water temperature (surface, mid-water, and bottom), salinity, and TGS in the truck will be measured at the beginning of each trial, and every 10 min thereafter, for 90 min. A YSI-85 will be utilized for water temperature and salinity measurements while a Sweeney saturometer (Sweeney Aqumatic, Stony Creek, Connecticut), will be used to determine TGS throughout each trial.

Rate of Oxygen Rise

The rate of O_2 rise in water containing 8 mg/L salt while running the air system only, the O_2 system only, and both the air and O_2 systems will be determined with gas flow through the airstones set at 2 L/min, 4 L/min, 6 L/min and 8 L/min. Oxygen cylinders will be set to 40 psi for all trials in which the O_2 system will be utilized. The O_2 dissipation rate while running the air system after achieving a high O_2 concentration ($\geq$16 mg/L) in the water will also be investigated. Air and ambient Delta water temperatures will be measured at the beginning and end of each trial using an Acu-Rite digital thermometer and a YSI-85, respectively. It will also be necessary to measure the ambient O_2 level in the Delta, which will be done with a YSI-85. All trials will be completed in the TFCF truck pit. The truck will be completely filled with 8 mg/L salt water and the appropriate gas system will be turned on. The gas flowthrough the airstones will be set at the 2 L/min, 4 L/min, 6 L/min or 8 L/min. Oxygen and TGS measurements, taken with a YSI-85 and a Sweeney saturometer, respectively, will be obtained every 2 min until five measurements are recorded on the plateau. The water in the truck tank will also be mixed every 2 min (after O_2 and TGS measurements are obtained), using a boat paddle, in order to simulate the mixing associated with water sloshing during transport. Each of the airstone flow rates will be tested for each treatment during this evaluation.

The O_2 dissipation rate while running the air system after obtaining a high O_2 concentration in the truck water will be investigated by first measuring the ambient air and Delta water temperatures, using an Acu-Rite digital thermometer and a YSI-85, respectively. The O_2 system will then be turned on and allowed to run, while mixing the water with a boat paddle, until the water in the truck contains an O_2 concentration of at least 16 mg/L. Oxygen concentration and TGS will be measured and verified using a YSI-85 and a Sweeney saturometer, respectively. After an O_2 concentration of at least 16 mg/L is achieved, the O_2 system will be turned off and the air system will be turned on for the remainder of the trial. Oxygen levels will then be measured every 2 min in order to determine the O_2 dissipation rate while using the air system in water that contains high concentrations of O_2.

Water Quality and Hauling Truck Fish Density

The water quality and hauling truck fish density evaluation will be completed using the same methods that were used by Sutphin and Wu in 2008 to evaluate the old bucket and trucks at the TFCF. Water quality will be measured during the loading, transport, and release stages of the TFCF fish-haul process. Sampling will be conducted during times when the Delta water temperature is warm (June–September) or when fish are being salvaged in great numbers. This will be done because these conditions likely result in the highest O_2 consumption, as well as CO_2 and TAN production rates (Sutphin and Wu 2008).

Water quality will be measured at seven stages during the loading, transport, and release processes: (1) in the holding tank prior to loading in the bucket, (2) in the bucket prior to loading of fish (O_2 only), (3) after loading into the bucket, but prior to loading in the truck, (4) in the truck before loading of fish (O_2 only), (5) after loading in the truck, but before the onset of transport, (6) after transport to the release site, but prior to release and (7) at the most commonly used release site (Emmaton Release Site). Obtaining O_2 measurements before and after fish insertion into the bucket and truck will allow us to get a crude estimate of O_2 consumption. In order to determine the water volume lost during the transport of fish, the distance (cm) that the surface of the water is from the top of the truck tank will be measured, using a tape measure, during stages three and four of the loading, transport, and release process. An 18.9-L bucket will be used to sample an appropriate amount of water from the surface of the holding tank prior to loading and transport. Water quality measurements in the truck will be taken from the mid-water column. Measurements will be collected at the release site 38 m offshore and at the water's surface, except for temperature, which will be recorded at 1.5, 4.6, and 7.6 m off the bottom. If possible, a YSI cord will be obtained that is long enough to take O_2 measurements on the bottom. This would be necessary if there is evidence that the water at the release site becomes stratified during the summer months.

Temperature and DO will be measured at each stage using a calibrated YSI-85. Carbon dioxide will be measured using CHEMetrics hand-held titration cells (CHEMetrics, Inc., Calverton, Virginia) while pH will be measured using an Oakton pH meter (Oakton Instruments, Vernon Hills, Illinois). Total gas saturation measurements will be obtained using a Sweeney saturometer and TAN will be measured using a LaMotte pH and TAN meter (LaMotte Company, Chestertown, Maryland). Un-ionized ammonia will be calculated using tables provided by Wedemeyer (1996), and incorporating TAN, pH, and temperature data collected during the water quality and hauling truck fish density evaluation.

Densities of fish during each haul-out will be estimated from 10-min entrainment sub-samples taken every 2 h in which all fish entering the holding tank are collected, identified and counted. The first 24 individuals of each sp. are measured (FL) during the 0200, 0600, 1400 and 1800 10-min sub-samples. The number of each sp. collected during the sub-sample is then extrapolated (multiplied by 12) in order to estimate the total number of fish entering the holding tank during each 2-h period. Fish weights, which are necessary to establish densities during transport, will be determined by establishing length-weight regression relationships for individual fish sp. sampled from the holding tanks, as was done by Sutphin and Wu in their 2008 evaluation of the old bucket and trucks at the TFCF.

Estimated fish densities will be used along with the measurements of O_2 and TAN taken at each of the seven stages during the loading, transport, and release processes in order to calculate crude estimates of the O_2 consumption and total ammonia production for the entire group of fish in each haul-out. This information will be used in the development of updated fish transport tables for use at the TFCF.

Data Analyses

Volume calculations will be made by dividing the amount of salt added to the new bucket and trucks by the maximum salinity achieved. Regression analysis will be used to determine salt dissolving rates. The development of a linear regression relationship of the amount of salt added vs. salinity in the new truck will allow for the determination of the appropriate amount of salt to add in order to achieve a concentration of 8 mg/L, which is the salinity required in the truck by the current BO. The rate of temperature and O_2 rise will also be evaluated using regression analysis by separately plotting temperature and O_2 concentration over time and generating rate curves for each treatment. Water volume loss during fish transport will be estimated by developing a regression of water surface distance from the top of the tank vs. volume. Water quality parameters of concern will be monitored at different fish densities to determine if they remain within acceptable limits for long-term fish culture as recommended by Wedemeyer (1996) as well as for comparison with the old system. The fish density that causes any of the water quality parameters to deviate from desirable levels will be determined.

Coordination and Collaboration

All work on this evaluation will be coordinated with the TFCF Fish Diversion Operators, TFCF Biology staff, and the Fisheries and Wildlife Resources Group. Participation and inclusion of research-related updates will be provided at regularly scheduled Tracy Technical Advisory Team (TTAT) and/or Central Valley Fish Facilities Review Team (CVFFRT) meetings.

Endangered Species Concerns

The water quality evaluation will not involve the take of any wild fish, including endangered or threatened species. The biological evaluation will not involve take of wild endangered or threatened species other than those salvaged during regular facility operations. Despite this, activities during the biological evaluation might slightly postpone haul-out of fish. All threatened or endangered species that are encountered will be left to be hauled-out and released.

Dissemination of Results (Deliverables and Outcomes)

The primary deliverable will be an article published in the Tracy Volume Series. Updates will also be provided at TTAT and CVFFRT meetings. Additionally, information will be gained on the successes and limitations of the fish-hauling process at the TFCF while using the new fish-haul trucks. This information will help guide future improvements to the fish transport procedures and equipment at the TFCF.

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